

PB84-191584

Residential Wood and Coal Combustion
Task 3. Health Effects Literature Search

Green (Del) Associates, Inc., Salem, OR

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Feb 84



U.S. Department of Commerce
National Technical Information Service

NTIS

PB84-191584

RESIDENTIAL WOOD AND COAL COMBUSTION

TASK 3

HEALTH EFFECTS LITERATURE SEARCH



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TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)								
1. REPORT NO. EPA-450/5-83-005c	2.	3. RECIPIENT'S ACCESSION NO. PBA 191584						
4. TITLE AND SUBTITLE Residential Wood and Coal Combustion - Task 3 Health Effects Literature Search		5. REPORT DATE February 1984						
7. AUTHOR(S) Barbara Burton and Alan Senzel		6. PERFORMING ORGANIZATION CODE						
9. PERFORMING ORGANIZATION NAME AND ADDRESS Del Green Associates, Inc. Environmental Technology Division P.O. Box 13446 Salem, Oregon 97309		8. PERFORMING ORGANIZATION REPORT NO.						
12. SPONSORING AGENCY NAME AND ADDRESS Pollutant Assessment Branch, SASD Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, N.C. 27711		10. PROGRAM ELEMENT NO.						
15. SUPPLEMENTARY NOTES		11. CONTRACT/GRANT NO. Purchase Order No. 40127NASA						
16. ABSTRACT This report is a compilation of titles and abstracts which is the result of a literature search for information on adverse health effects due to air emissions (indoor or outdoor) from the residential combustion of coal and wood. Abstracts are presented alphabetically according to the first author's surname. This search included the files of the Combustion Research BRANCH, Industrial Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, N.C.; and Environmental Technology Division, Del Green Associates, Inc., Woodburn, Oregon, which has recently completed a residential wood combustion study for U.S. EPA Region X and the State of Oregon. In addition, an on-line computer literature search was performed, covering the following data bases: Biological Abstracts (BIOSIS, 1976+), National Technical Information Service (NTIS), and Excerpta Medica (1976+).		13. TYPE OF REPORT AND PERIOD COVERED Final						
17. KEY WORDS AND DOCUMENT ANALYSIS		14. SPONSORING AGENCY CODE EPA						
<table border="1"> <thead> <tr> <th>a. DESCRIPTORS</th> <th>b. IDENTIFIERS/OPEN ENDED TERMS</th> <th>c. COSATI Field/Group</th> </tr> </thead> <tbody> <tr> <td>Air Pollution Combustion Residential bituminous coal/combustion Residential Anthracite coal combustion Residential wood combustion Carcinogens Residential combustion/heating</td> <td>Smoke Health Effects Respiratory Diseases POM CO Suspended particulate matter Stationary sources Hazardous air pollution</td> <td></td> </tr> </tbody> </table>			a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	Air Pollution Combustion Residential bituminous coal/combustion Residential Anthracite coal combustion Residential wood combustion Carcinogens Residential combustion/heating	Smoke Health Effects Respiratory Diseases POM CO Suspended particulate matter Stationary sources Hazardous air pollution	
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18. DISTRIBUTION STATEMENT Unlimited		19. SECURITY CLASS (This Report) Unclassified						
		20. SECURITY CLASS (This page) Unclassified						
		21. NO. OF PAGES 75						
		22. PRICE						

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February, 1984

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PREFACE

The following compilation of titles and abstracts reflects the results of a literature search to obtain information on adverse health effects due to air emissions (indoor or outdoor) from the residential combustion of coal and wood. Abstracts are presented alphabetically according to the first author's surname.

Relevant literature was gleaned from the files of the Combustion Research Branch, Industrial Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC; Environmental Sciences Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC; and Environmental Technology Division, Del Green Associates, Inc., Salem, Oregon, which had recently completed a Residential Wood Combustion Study for EPA Region X and the State of Oregon.

In addition, an on-line computer literature search was performed, covering the following data bases: Biological Abstracts (BIOSIS, 1976+), Index Medicus (MEDLINE, Backfile, 1972+), National Technical Information Service (NTIS), and Excerpta Medica (1976+).

We believe this literature search to be thorough and to represent the bulk of the available current information on this subject matter.

All papers noted as a presentation at the 1981 International Conference on Residential Solid Fuels, June, 1981, may be found in Residential Solid Fuels, Environmental Impacts and Solutions, (Eds.) Cooper, John A. & Malek, Dorothy, published by Oregon Graduate Center, Northwest Environmental Research Center, Beaverton, Oregon.

Allwine, K.J., Jr. Assessment of the Long-Range Transport of Residential Woodstove Fine-Particulate Emissions for Two Future United States Energy Scenarios, Battelle Pacific Northwest Labs., Richland, WA, May, 1981. Presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon.

Abstract: This analysis of the impact of solar energy technologies (especially woodstoves) on regional scale fine particulate air quality resulting from direct-energy-use sources is a good first-order approximation. In general, it was shown that significant interregional transport of fine particulates can occur, especially into the three northeastern regions of the U.S. No regional scale air pollution problems were identified, unless at a later time one of the toxic materials present in fine particulates is found to be harmful at the fine particulate concentrations reported. Results also indicate that concentrations are low relative to any current particulate standards. The maximum in 1975 was computed to be $3.54 \mu\text{g}/\text{m}^3$ for the Middle Atlantic region decreasing to a maximum in 2000 of $2.83 \mu\text{g}/\text{m}^3$ (high scenario) for the New York-New Jersey region. The maximum from woodstoves was computed to be $.27 \mu\text{g}/\text{m}^3$ in 1975 and $.82 \mu\text{g}/\text{m}^3$ in 2000 (high scenario). Both maximums occurred in the Middle Atlantic region. The concentrations in the eastern five regions are predicted to decrease from 1975 to 2000 (both scenarios), whereas the opposite is true for the western five regions. The contributions from woodstoves are projected to increase in all regions. Higher concentrations are predicted for the high scenario than for the low scenario for all regions. The increase ranges from $.01 \mu\text{g}/\text{m}^3$ in the Mountain region to $.26 \mu\text{g}/\text{m}^3$ in both the Middle Atlantic and Southeast regions. The majority of this increase is due to woodstoves. For the

three northeastern regions, more than 50 percent of the impact on each region is from outside the respective region. (EPA citation 06:033761)

Ayer, Franklin, A. Proceedings of the Conference on Wood Combustion Environmental Assessment Held at New Orleans in February, 1981,
Research Triangle Institute, Research Triangle Park, NC.

Abstract: These proceedings document presentations at the conference. The objective of the conference was to disseminate recent research and development findings on the subject of residential wood combustion. The conference sessions dealt with: (1) an overview of environmental assessment activities, (2) specific emissions and heating efficiency assessments, (3) emissions control techniques, (4) highlights of the first three sessions, and (5) residential wood combustion issues and their resolution. In summary, the previously reported high concentrations of polycyclic organic matter (POM) in residential wood stove emissions were verified by several papers. One paper even reported high POM concentrations in the indoor environment of homes with wood stoves. High ambient values were not attributed to residential wood combustion, but many of the ambient impact studies were just beginning. Emission control techniques which were considered for controlling organic emissions included secondary combustion and the introduction of a combustion catalyst. These two control techniques were already being marketed; however, their reliability and structural stability were questioned by several researchers. Future regulation of wood stove emissions was considered unlikely due to problems relating to enforcing a residential emission standard.

Bagchi, N.J.; Zimmerman, R.E. An Industrial Hygiene Evaluation of Chimney Sweeping, Division of Health, State of Wisconsin, Madison, Wisconsin, 1980, American Industrial Hygiene Association Journal, 41 (4), 1980, pp. 297-299.

Abstract: With the increased use of wood and coal for home heating, chimney sweeping is becoming a more common occupation. A preliminary study was designed to evaluate the air contaminants present in the process. Arsenic and sulfur dioxide were found along with coal tar pitch volatiles. A method of minimizing the exposure of these chemicals to chimney sweeps by spraying a water mist is discussed.

Barnea, M.; Barnea, E.; Pacuraru, N. Increase of the Frequency of Some Diseases (Bronchitis, Pneumonia, ENT Diseases, and Conjunctivitis) among the Population of a Locality Polluted by Coal Combustion (French), Institute of Hygiene, Sante Publication, Bucharest, 1976.

Abstract: Domestic heating may, because of its characteristics, be an important factor in the pollution of the atmosphere, with implications for the health of the population. In the locality studied, with air polluted by small coalburning power stations, an increased incidence of certain diseases was noted, notably bronchitis, pneumonia, ENT disorders and conjunctivitis, as compared with another control locality. The effect of pollution of the urban atmosphere as a promoting factor was more obvious in the group of households in which the interference of other risk factors is less. Although no potentiation is noted between urban and industrial pollution, it must be stressed that the pathology studied is higher in women exposed to both urban and occupational pollution. The effects of the pollution of the atmosphere on the body facilitate the onset of several disorders in the same person. Respiratory morbidity is quite high among women as compared with men, which shows that not only smoking, but also the pollution of the atmosphere, may, from this standpoint, be an important risk factor.

Barnett, Stockton G.; Shea, Damian. Effects of Woodstove Design and Operation on Condensable Particulate Emissions, Department of Earth Sciences and Department of Chemistry, State University of New York, Plattsburgh, NY, 1981, presented at the 1981 International Conference on Residential Solid Fuels, June, 1981, Portland, OR.

Abstract: The authors have developed a simple, effective, and low-cost technique to measure condensable particulates in woodstove flue gases. A high volume sampler was designed which concentrates flue gas particulates on filter paper. Room air bleeds into the sampler tube, cooling flue gases, and thereby insuring complete condensation of the flue gases into droplet form before they reach the filter paper.

Flow rates of both flue and sampler were monitored. After months of testing different flowmeters, the Teledyne Hastings Raydist (PCI-30) thermopile-type flowmeter was found to produce the most reliable measure of flue gas velocity without being affected by either high temperature or by liquid flue gas droplets.

Emission tests were made using native hardwoods of 4- to 6-inch diameter with an oven-dry-basis moisture content of 30-40% (average for home use).

Results are included of an investigation of wood burning rates encountered in 10 homes in northernmost New York. Average burn rate was found to be only 3.5 pounds per hour. In accordance with these results, our emissions tests were made at burning rates averaging about 4 pounds per hour and ranging from 1.5 to 6 pounds per hour.

Conclusions from 61 emissions sample runs:

Barnett, Stockton G. (Continued)

1. The probable error for our technique is +20-25% of the reported emission factor value (emission factor being the quantity of particulates per unit of wood burned).
2. Emissions release is generally, though not always, greater near the beginning of a burn cycle.
3. Emission factors decrease dramatically as burn rate is increased.
4. Wood moisture has little effect on emission factors. Dry wood (less than 25% moisture content) may produce slightly higher emissions than the commonly occurring 30-40% moisture wood. However, when very wet wood is burned, higher emission factors may emit from the stove because the stove smolders and the relationship in Conclusion 3 above becomes dominant.
5. Small logs (similar in size to brands) produce markedly increased emission factors.
6. Emissions testing of 12 different stoves indicates that stove design can affect emission factors but, surprisingly, the group of cleanest burning commercially available stoves contained stoves from each of the traditional categories (box, step, horizontal baffle, and crossdraft). (An experimental prototype stove, a variation of the crossdraft principle, produced lower emission factors than this group, and both a thin-walled convective heater and an inclined baffle stove produced significantly higher emission factors.)
7. Simple, inexpensive modifications to a thin-walled convective

Barnett, Stockton G. (Continued)

box heater produced emission factors almost 50% lower than those of the stock stove.

8. Changes in draft air location and degree of preheating produced little, if any, change in emission factors on a box stove.
9. The use of a new thermostat developed by Barnett caused no change in emission factors of the three stoves to which it was applied. However, since the new device provides a wood savings of about 20% to the homeowner, total atmospheric loading of particulate is reduced.

Beck, Barbara D.; Brain, Joseph D. Prediction of the Pulmonary Toxicity of Respirable Combustion Products from Residential Wood and Coal Stoves, Department of Physiology, Harvard School of Public Health, Boston, MA, presented at the Speciality Conference on Residential Wood and Coal Combustion, March, 1982, Louisville, Ky.

Abstract: Respirable particles from combustion of anthracite coal, bituminous coal, and wood in residential heating stoves were tested for their potential to cause pulmonary disease in a short-term assay using hamsters exposed by intratracheal instillation. One day after exposure, the animals were sacrificed, their lungs lavaged, and the lavage fluid examined for biochemical and cellular indicators of pulmonary damage. The products of anthracite and bituminous combustion caused extensive edema, reduction in macrophage numbers, and impairment of macrophage phagocytic activity. Overall, the intensity of response was comparable to that produced by the same mass of the highly toxic mineral dust alpha-quartz; however, for some assays, the response to the coal products was greater than quartz, whereas for others it was less. This difference in pattern of response suggests that the pathological lesions produced by inhalation of coal combustion products may differ from those produced by alpha-quartz inhalation. The response to the wood combustion products was less than the response to the coal products, although it was usually elevated over the response to iron oxide, a nontoxic mineral dust. The coal combustion products were quite acidic ($\approx$ pH 1.5 for a 2.5% suspension) and contained 25 to 35% sulfate by weight. Neutralization diminished some, but not all, of the biological responses to the bituminous coal products.

Bencko, V.; Symon, K. Health Aspects of Burning Coal with a High Arsenic Content, Part 1: Arsenic in Hair, Urine, and Blood in Children Residing in a Polluted Area, Environmental Research 13 (3), 1977, pp. 378-385.

Abstract: Arsenic determination was carried out on hair, urine, and blood samples taken from groups of 10 year-old boys, each numbering 20 to 25 individuals, residing in a region polluted by arsenic. The source of arsenic emissions (1/2 to 1 ton per day) is a power plant burning local coal of high arsenic content. In all the materials examined, considerably elevated concentrations of arsenic were found. The relation of the observed levels of arsenic to the distance from the place of residence, up to a distance of more than 30 km from the source of the emissions, was studied. On the basis of the results obtained, the most advantageous material for estimation of nonoccupational exposure to this toxic agent seems to be hair, in spite of some problems with the decontamination procedure involved. The results corresponded to the theoretical ideas on spreading of emissions from elevated sources in the open air and tend to establish the applicability of arsenic determination in the hair as a direct exposure test of contamination of the environment by arsenic. Considerable variability among individual arsenic values in the hair makes group examination a necessity. The same applies to the urine and blood sampling, which is complicated by several technical difficulties. Levels in urine reflect the quantities of arsenic inhaled or ingested after their absorption into the blood, and give a more realistic picture of possible daily intake.

Bencko, V.; Symon, K. Test of Environmental Exposure to Arsenic and Hearing Changes in Exposed Children, Environmental Health Perspectives (U.S.A.), 1977, Vol. 19 (pp. 95-101).

Abstract: Arsenic determination was carried out on hair, urine, and blood samples taken from groups of 10 year-old boys, each numbering 20 to 25 individuals, residing in a region polluted by arsenic. In all the examined materials, considerably elevated concentrations of arsenic were found. The relation of the observed levels of arsenic to the distance from the place of residence, up to a distance of more than 30 km from the source of the emissions, was studied. On the basis of the results obtained, the most advantageous material for estimation of nonoccupational exposure to arsenic seems to be hair, in spite of some problems with the decontamination procedure involved. Considerable variability among individual arsenic values in the hair makes group examination a necessity. Hearing changes were analyzed in a group of 56 ten-year-old children residing near a power plant burning local coal of high arsenic content. The results of both audiometric and clinical examination were compared with those of a control group numbering 51 children of the same age living outside the polluted area. The highly standardized audiometric and clinical examinations were completed with a questionnaire analysis concerning the personal medical histories of the children. The obtained data were elaborated statistically by means of the chi square test. Important hearing losses were found at frequencies of 125, 250, and 8000 Hz, especially at the lowest range. Significant degrees

Bencko, V. (Continued)

of hearing loss were found in bone conduction as well as in the corresponding ranges of frequencies. The high statistical significance of the hearing impairments found point to very low probability of their being only an "accidental" finding. The possibility of toxic damage to the ear cannot yet be excluded.

Bencko, V.; Vasilieva, E.V.; Symon, K. Immunological Aspects of Exposure to Emissions from Burning Coal of High Beryllium Content, Environmental Research, 22 (2), 1980, pp. 439-449.

Abstract: An epidemiological study was conducted on groups of people exposed occupationally (45 persons) and nonoccupationally (36 persons) to the combustion products of coal containing a comparatively high concentration of beryllium. The concentration of beryllium in the working atmosphere ranged between 30 and $800 \times 10^{-5} \text{ mg/m}^3$, in the town S, dwelling place of a nonoccupationally exposed cohort, between 0.39 and $1.68 \times 10^{-5} \text{ mg/m}^3$. A group of 100 subjects who had no occupational contact with beryllium or other industrial toxic agents, and who lived outside of the pollutant region, served as control cohort. In all examined persons, the main classes of immunoglobulins and autoantibodies (lung, heart, liver, spleen, thyroid gland, suprarenals, and native DNA) and antibodies against nuclear (ANA) and mitochondrial (AMA) antigens (obtained from the lungs of intact and of experimental berylliosis rats) were determined. In both exposed groups, elevated levels of IgG and IgA and increased concentrations of autoantibodies were found in comparison with the control cohort of people. Specific AMA and ANA were also found in both the exposed groups, with higher levels in women. The demonstrated immunological changes in humoral immunoreactivity might be considered as signs of beryllium exposure. In the discussion, the authors emphasize the increasing importance of immunological aspects in the study of environmental pollution.

Benton, Gary; Miller, Don Paul; Reimold, Mary; Sisson, Richard.
A Study of Occupant Exposure to Particulates and Gases from Woodstoves
in Homes, as presented at the 1981 International Conference on Resi-
dential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: The air within five rural Kansas homes which used wood fuel was
sampled for particulates and gases during the 1980 heating season.

The mass respirable particulate levels in the five homes were found to be
higher than average for this area. The gases ranged from near zero to a
substantial level. Each home had a unique set of components which
remained consistent throughout the study. The components identified
appeared to be dependent on the type of wood burning device used.

Boldi, Robert (Principal Investigator), Steffel, Richard (Research).
Sulfur Dioxide Emissions from Residential Coal-Fired Devices and Their
Impact upon Air Quality in Missoula, Montana, Western Montana Scientists'
Committee for Public Information, presented to the Missoula County
Department of Health, January, 1982.

Abstract: As the cost of natural gas and electricity continues to rise,
increased reliance upon alternative forms of energy is probable.

The possibility of increased coal utilization as a source of heat
during the winter requires an understanding of the consequences of coal
combustion upon the air quality of the valley. The following is a
brief review of the market forces which may lead to increased coal use,
projections of energy demands likely to be met with coal, a review of
the possible health effects of coal combustion products, and estimates
of the expected ambient air concentrations of sulfur dioxide as a
function of daily emission rate.

Braunstein, J.M.; Kornegay, F.C. Environmental and Health Aspects of Biomass Energy Systems, Chemical Congress of the North American Continent, Las Vegas, NV, August 24, 1980.

Abstract: In a recent study undertaken to ensure the early incorporation of environmental considerations in decisions concerning biomass-to-energy systems, a number of issues emerged indicating the need for early attention to environmental, socioeconomic, and health concerns. Both production of biomass as well as conversion can lead to environmental impact, and although most impacts will be site-specific, some generic effects can be identified. The most important potential impacts arise first, from the need for large-scale commitment of resources for production, and second, from uncontrolled widespread small-scale utilization. Because biomass-related impacts cover a very broad spectrum of materials, processes, end products, and effects, the discussion presented here, except for an overview of generic effects and comment on production impacts, will be directed primarily to those resulting from residential wood combustion. (EPA citation 05:034116)

Butcher, S.S.; Sorenson, E.M. A Study of Wood Stove Particulate Emissions, Journal of the Air Pollution Control Association, 29 (7), 1979, pp. 724-728.

Abstract: Particulate emission factors for two wood stove models were determined for two types of fuel and a range of operating conditions. The emission factors range from 1 g/kg (fuel) to 24 g/kg. A model is presented which represents the emission factor as a simple function of the ratio of fuel load to combustion rate, or the length of time between refueling. This model is apparently appropriate for evaluating the impact of wood-based residential space heating on ambient air concentrations of particulate matter if certain assumptions can be made about stove operating conditions. An application of the emission factor model to a typical community suggests that the contribution of wood stoves to ambient particulate levels might reach $100 \mu\text{g}/\text{m}^3$ if the entire heating load were carried by wood. Preliminary analyses of the particulate matter indicate that benzene extractables range from 42% of the total particulate mass at short refuel times to 67% at longer refuel times. About 45% of the mass of benzene extractables appeared in the neutral fraction of acid-base extractions. Polycyclic aromatic hydrocarbons are expected in this neutral fraction.

Carlson, James H. Residential Wood Combustion in Missoula, Montana: An Overview of Its Air Pollution Contributions, Health Effects, and Proposed Regulatory Solutions, Missoula City-County Health Department, Missoula, Montana, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: In the past decade, residential wood combustion (RWC) has replaced industry as the largest contributor to Missoula's wintertime air pollution problem. Recent studies indicate that RWC is responsible for approximately 55 percent of wintertime TSP and 75 percent of wintertime RSP.

Pulmonary function testing indicates that TSP in Missoula at annual average levels of 80 to 90 $\mu\text{g}/\text{m}^3$ cause measurable health effects in grade school students and in persons with chronic obstructive pulmonary disease. Microbial bioassay tests have indicated that Missoula particulate contains elevated levels of mutagenic substances which are attributed to wood combustion.

Missoula citizens have exhibited concern over air quality, and surveys indicate that government efforts are necessary to alleviate the problem. Citizen groups and Health Department staff have proposed increased public education efforts and stringent emission standards for the installation of new wood-burning devices.

Cart, E.N. Jr.; Farmer, M.H.; Jahnig, C.E.; Lieberman, M.; Spooner, F.M. Evaluation of the Feasibility for Widespread Introduction of Coal into the Residential and Commercial Sectors, Volume I, Executive Summary and Volume II, Technical Section, Exxon Research and Engineering Co., Linden, NJ, August, 1977.

Abstract: A study was carried out to assess the environmental and energy conservation potential for widespread use of coal in the residential and commercial sectors. The study was restricted to using coal in some form to supply space heat for the residential and commercial sectors. The study considered the environmental impact of increased use of coal using published emission factors. Energy utilization and economics were considered, as well as the institutional factors associated with widespread use of coal. The technologies covered included direct use of coal in conventional furnaces or boilers, as well as fluid bed combustion, plus indirect use via coal-derived SNG, district heating, and electric heating (resistance or heat pump) based on coal-fired power plants.

Church, Scott (Principal Researcher). Residential Wood Burning and Its Impact on Particulate and Carbon Monoxide Emissions in the Missoula Urban Area, 1979-80, Missoula City-County Health Department.

Abstract: During the Spring of 1980, a household survey of the Missoula Urban Area was conducted as a follow-up to a 1976 survey. The survey sought to determine the percentage of wood-burning households, the quantity of wood being burned, and the resultant amount of particulate and carbon monoxide produced for the 1979-80 burning season. Other parts of the survey were designed to quantify the number and types of burning equipment, periods of the day in which people burn most often, and the chances of installing burning equipment within the next two years. Results of the survey were applied to the total household population, with a percentage breakdown for areas of similar socioeconomic characteristics which followed census tracts within the Missoula Urban Area.

Projections for wood-burning emissions were made for the 1981-82 and 1983-84 burning seasons. Additionally, an updated particulate and carbon monoxide emission inventory was compiled to reveal the contributions of residential wood burning to each.

Citizens' Air Pollution Working Groups. Mutagenic Substances Associated with Particulate Pollutants, presented to the Missoula City-County Air Pollution Control Board, April, 1981.

Abstract: Not available.

Colome, S.D.; Spengler, J.D. Residential Indoor and Matched Outdoor Pollutant Measurements with Special Consideration of Wood-Burning Homes, Program in Social Ecology, University of California, as presented to the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: Results are presented for trace-element determinations of "respirable" (3.5 μ m 50% cut-off) aerosols for the five homes each in Steubenville, Ohio and Portage, Wisconsin. Sampling was conducted every twelfth day for one year during 1978 and 1979 and is matched within residence and immediately outside and across the five home sites in each city. A total of approximately 600 samples have been analyzed by instrumental neutron activation analysis and separately for mass, water soluble sulfates, SO₂ and NO₂. While not designed to investigate the influence of solid residential fuel, two of the homes in Portage use wood for primary heating.

Across the full set of homes, the indoor concentrations of SO₄, Mn, and V were generally related to the matched outdoor observations. Concentrations of other parameters measured showed less relationship and indicated the presence of indoor sources. Homes in which wood was used for heating tended to have a weak indoor excess of Al, Cl, Mn, and possibly Br. This could have been due to other, unidentified, indoor sources. Modification of exposure to outdoor pollutants by indoor environments has implications for epidemiologic investigations of air pollution.

Cooke, W.M.; Allen, J.M.; Hall, R.E. Characterization of Emissions from Residential Wood Combustion Sources, Battelle-Columbus Laboratories, as presented to the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: The purpose of this study was to investigate combustion modification techniques that might be beneficially applied to wood stoves, specifically to identify those techniques that hold promise of providing a significant improvement in emissions from residential wood combustion. Three commercial stoves were tested under different burn modes. Stove operating conditions included up draft using a grate, up draft using a hearth, cross draft, down draft, and a high turbulence mode utilizing a forced draft blower. Several fuels were tested, including commercial oak cord wood, commercial green pine cord wood, oven-dried fir brands, and naturally dried oak cut into reproducible triangles. Continuous flue gas measurements taken during the burn cycle included O_2 , CO_2 , CO, NO, SO_2 , and total hydrocarbons (THC). In addition, discrete samples of flue gas were collected throughout several runs by a Modified Method 5 sample train. These gas and particulate samples were analyzed for a series of PAH compounds using high resolution, glass capillary gas chromatography and coupled mass spectrometry. Emissions of total PAH and benzo(a)pyrene are reported relative to flue gas composition and burning mode.

Several combustion modification techniques were identified which have an appreciable effect on emissions and, therefore, can be developed and applied to reduce emissions in consumer use. The more promising

Cooke, W.M. (Continued)

design modifications include: prevention of heating wood inventory in the stove, direction of the air supply into primary and secondary burning areas with high turbulence, increases in the temperature in secondary burning regions of the appliances, and any means of increasing the effectiveness of secondary combustion.

Cooper, J.A. Environmental Impact of Residential Wood Combustion Emissions and Its Implications, Journal of the Air Pollution Control Association, 30 (8), 1980, pp. 855-861.

Abstract: Currently available information suggests a substantial environmental impact from residential wood combustion emissions. Air pollution from this source is widespread and increasing. Current ambient measurements, surveys, and model predictions indicate winter respirable emissions from residential wood combustion can easily exceed all other sources. Both the chemical potency and deliverability of the emissions from this source are of concern. The emissions are almost entirely in the inhalable size range and contain toxic and priority pollutants, carcinogens, co-carcinogens, cilia-toxic, mucus coagulating agents, and other respiratory irritants such as phenols, aldehydes, etc. This source is contributing substantially to the nonattainment of current particulate, carbon monoxide, and hydrocarbon ambient air quality standards and will almost certainly have a significant impact on potential future standards such as inhalable particulates, visibility, and other chemically specific standards. Emissions from this growing source are likely to require additional expenditures by industry for air pollution control equipment in nonattainment areas.

Cooper, J.A.; Currie, L.A.; Klouda, G.A. Assessment of Contemporary Carbon Combustion Source Contributions to Urban Air Particulate Levels Using Carbon-14 Measurements, Environmental Science and Technology, 15 (9), 1981, pp. 1045-1050.

Abstract: Measurement of carbon-14 activities with new low-level counting methods has been demonstrated to be an effective tool for assessing the contribution of contemporary carbon combustion sources to the mass collected with typical high-volume air samplers. This study represents the first time that radiocarbon measurements have been applied to fine particles ($<2 \mu\text{m}$) and used to assess the contribution of specific sources to urban air quality. Radiocarbon analysis of fine particles minimized interferences from large particles such as pollen, spores, wood fiber, etc., and improved the method's ability to assess the impact of burning vegetative material such as field and slash burning and space heating with wood. Slash burning contributed between 39 and 70% of the fine particulate mass while field burning contributed 50% of the total suspended particulates (TSP) on high-impact days in the Portland and Eugene, Oregon airsheds. Radiocarbon analysis of filters selected for high impact from residential wood combustion shows that this source is a substantial contributor to fine particulate mass during winter months in Portland, Oregon.

Cooper, J.A.; DeCesar, R.T. Missoula, Montana Source Apportionment Study, NEA Laboratories, Beaverton, Oregon, prepared for the Montana State Department of Health and Environmental Services, Helena, Montana, 1980.

Abstract: Respirable ($<2.5 \mu\text{m}$) and coarse ($>2.5 \mu\text{m}$, $<15 \mu\text{m}$) suspended air particles were collected in a residential area of Missoula, Montana during the winter of 1979 to evaluate the impact of emissions from residential wood combustion (RWC) on air quality. Instrumental neutron activation analysis, x-ray fluorescence, and combustion-flame ionization organic-elemental carbon analysis methods were used to develop chemical fingerprints which were analyzed by chemical mass balance methods.

Residential wood combustion emissions contributed 68% of the respirable particles, while motor vehicle exhaust, urban dust, and hogged fuel boilers contributed 6%, 9%, and 2%, respectively. Urban road dust accounted for 54% of the coarse material during the study period.

Substantial experimental problems developed during the sampling which limited the extent of the conclusions.

Curtiss, J.R.; Grahn, D. Population Characteristics and Environmental Factors that Influence Level and Cause of Mortality: A Review, Journal of Environmental Pathology and Toxicology, 4 (2-3), 1980, pp. 471-511.

Abstract: Responsible evaluation of energy production effects on human health requires prior accounting for the socioeconomic, cultural, and climatic characteristics known to influence mortality rate and cause. Fifteen population characteristics and environmental variables (education, income, occupation, industrial mix, socioeconomic status, housing quality, climate, urban residence, geographic residence, internal migration, cigarette consumption, alcohol consumption, marital status, foreign birth or stock, and religious affiliation) and three age subgroups are discussed. An initial set of eight variables is indicated for mortality rate standardization, based on the reliability of their relationships with mortality. These eight variables are: education, occupation, industrial mix, urban residence, marital status, ethnic mix, and cigarette and alcohol consumption. Education and occupation are negatively related to mortality. Occupational exposure to toxicants (indicated by industrial mix), cigarette consumption, and alcohol consumption have positive linear relationships with various specific causes of mortality. Urban residence, marital status, and ethnicity have nonlinear relationships with mortality and show consistent patterns for certain causes of death. In addition to these characteristics, three age subgroups (<1 year, 1-14 years, >or = 65 years) are discussed because of their relatively high or low rates compared to the rest of the population.

Curtiss, J.R. (Continued)

A brief review of water and air pollution effects on mortality is included for completeness. Unique to this review is the quantitative summary (presented as an appendix) of the variables influencing adult mortality. It is a compilation of numerical relationships, derived either directly or indirectly from the published data, that support the choice of influencing variables.

DeAngelis, D.G.; Reznik, R.B. Source Assessment: Coal-Fired Residential Combustion Equipment Field Tests, June, 1977, Monsanto Research Corporation, Dayton, Ohio, 1978. EPA/600/2-78/0040.

Abstract: The report gives results of a study to quantify criteria pollutants and characterize atmospheric emissions from coal-fired residential heating equipment. Flue gas was sampled from a warm air furnace and a hot water boiler which burned three western coals. Tests were conducted with the stokers operating on a 20-minute ON/40-minute OFF cycle, corresponding to high- and low-fire conditions in the fuel bed. Variations in coal composition and type of heating equipment both influenced emission rates, and the OFF portion of the heating cycle contributed significantly to total emissions. The report gives a number of correlations between emission rates and test parameters. Combustion efficiencies for coal-fired residential heating equipment were lower than for larger coal-fired systems (e.g., utility boilers), as evidenced by the higher emission levels for CO and organic species, including POMs. In contrast to previous estimates, particulate emissions were not a function of the coal ash content, but did correlate with the coal free swelling index and volatile content. The particulate composition was primarily carbon, indicating that the particles were not formed from coal ash, but from carbonaceous material volatilized during combustion.

DeAngelis, D.G; Reznik, R.B. Source Assessment: Residential Combustion of Coal, Monsanto Research Corporation, Dayton, Ohio, 1979.
EPA-600-2-79-019A.

Abstract: The report summarizes the assessment of air emissions from the residential combustion of anthracite, bituminous, and lignite coals, with emphasis on bituminous coals. Approximately 2.6 million metric tons of coal were burned as a primary source of heat in an estimated 493,018 housing units in 1974. Geographical distribution of coal-fired heating devices is related to the location of major coal fields. Stoker-fed boilers and warm-air furnaces are currently being marketed for burning coal as a primary source of heat in residential structures; however, hand-fed units and room heaters also exist. Emissions from these units include particulates, SO_x , NO_x , CO, hydrocarbons, polycyclic organic material (POM), and trace elements. The severities of these emissions were assessed for an average source. Emissions of POMs were found to have a severity of 2.6 for combustion of bituminous coal; the remaining emissions had severities of 0.05 or less. A special assessment of the environmental impact of an array of 100 houses burning coal indicates the potential for a 30-fold increase in the severities of associated emissions.

DeAngelis, D.G.; Ruffin, D.S.; Reznik, R.B. Preliminary Characterization of Emissions from Wood-Fired Residential Combustion Equipment, Monsanto Research Corporation, Dayton, Ohio, 1980. EPA 600/7-80-040.

Abstract: This report describes a study conducted to quantify criteria pollutants and characterize other atmospheric emissions from wood-fired residential combustion equipment. Flue gases were sampled from a zero clearance fireplace and two airtight cast iron stoves (baffled and non-baffled design). Four wood types were tested, oak-seasoned and green and pine-seasoned and green. Samples were analyzed for particulates, condensable organics, nitrogen oxides, carbon monoxide, sulfur oxides, organic species, and individual elements.

DeAngelis, D.G.; Ruffin, D.S.; Peters, J.A.; Resnik, R.B. Source Assessment: Residential Combustion of Wood, Monsanto Research Corporation, Dayton, Ohio, 1980. EPA-600/2-80-042B.

Abstract: The report gives results of an estimate of the potential environmental impact of the residential combustion of wood. About 16.6 million metric tons of wood was burned in the residential sector in 1976. About 30% of this was burned for primary heating in about 912,000 residential units. Geographic distribution of wood-fired heaters is related to the natural forest regions in the U.S. By 1985, over 10 million homes will be using some wood fuel. Emissions from wood-fired residential heaters include particulates, SO_x , NO_x , CO, hydrocarbons (HC), and polycyclic organic materials (POM). The impact of these emissions has been assessed by source severity, involving estimating maximum ground level concentrations of pollutants and comparing these concentrations to a National Ambient Air Quality Standard for criteria pollutants or to a reduced threshold limit value for noncriteria pollutants. A comparative analysis of source severities for residential wood combustion with other stationary sources indicates that residential wood combustion is a major source of POM. Particulate, HC, and CO emissions from all residential wood-fired sources were estimated to contribute 1.0, 1.5, and 3.8% respectively, of the total national emission burden for those species in 1976.

Department of Energy, Washington, D.C. Health Effects of Residential Wood Combustion: Survey of Knowledge and Research, Office of Environmental Assessments, 1980.

Abstract: Health and safety issues related to residential wood burning are examined. Current research and findings are also described, and research status is assessed in terms of future health and safety requirements. (EPA citation 06:002170)

Evans, D.W.; Wiener, J.G.; Horton, J.H. Trace Element Inputs from a Coal-Burning Power Plant to Adjacent Terrestrial and Aquatic Environments, Journal of the Air Pollution Control Association, 30 (5), 1980, pp. 567-573.

Abstract: Inputs of trace elements derived from coal ash to terrestrial and aquatic environments were investigated near an 83 MW coal-burning power plant. Comparisons were made between terrestrial inputs of trace elements through aerial deposition during 23 years before installation of electrostatic precipitators and aquatic inputs from ash disposal basins after installation. A gaussian plume model was used to predict deposition patterns of 29 trace elements in coal ash about the power plant. Detectable increases of only Sr, As, Ab, and Be in surface soils within 3 km of the power plant were predicted. Concentrations measured in surface soils were largely consistent with these predictions. Measurements of aerial deposition of Cd, Pb, Cu, and Mn at a site 5.5 km distant were similar to those in other rural areas and indicated that little of the measured Cd, Cu, Mn, or Pb was derived from fly ash. Concentrations of 12 heavy metals in effluents from the basin receiving ash were comparable to those predicted in rainfall deposited nearest the plant. It is concluded that at other coal combustion facilities, basin disposal could be a more serious contamination threat to aquatic environments than aerial dispersal of ash.

Falk, H.L.; Jurgelski, W., Jr. Health Effects of Coal Mining and Combustion: Carcinogens and Cofactors, Environmental Health Perspectives. (U.S.A.), 33, 1979, pp. 203-226.

Abstract: Some polynuclear aromatics (PNA) have been found to be potential carcinogens for all tissues and organs of experimental animals that have been exposed to them, but different dose levels are needed for these effects. They have been known for decades to cause cancer at the site of application, but also at certain sites distant from the area of contact. Although some hydrocarbons are potent and complete carcinogens, the majority of related hydrocarbons were originally found to be inactive. Since they generally appear together, it was important to know more about their interaction, particularly whether they would synergize or antagonize. The polycyclic hydrocarbons have been studied by subcutaneous injection, where they prove very potent carcinogens. They are also very active on the skin of mice, where they produce cancer on prolonged application. Inhalation studies, requiring larger doses, yielded negative results until particulate matter was introduced, which facilitated the development of lung tumors. Although iron oxide dust was used initially, other dusts were also capable of enhancing the response of the tissue to benzo(a)-pyrene carcinogenesis. This point is of importance, particularly since the inhalation of PNA in situations of air pollution or coal mining involves particulates, although of a different type. Soot is not a homogeneous substance, and several factors determine its properties. Soots will lose some of their absorbed chemicals during their residence in air, but they retain their PNAs for long periods of time when they

Falk, H.L. (Continued)

reach the soil. The carcinogenicity of PNAs in the adsorbed state may be completely absent, depending on particle size of the soot and availability of eluting capability of the tissues or cells in contact with the soot. Whenever the carcinogenic polynuclear aromatics can be eluted, they will be active in producing cancer if their residence time is adequate. There seems to be no reason to assume that a large increase in coal combustion in the future will by necessity lead to greater risks of cancer to the coal miners or the general urban dweller, because activities to be started now can take into consideration the requirements necessary for control of air pollution in mines as well as in cities. If new uses of coal will be developed, it will be a completely different situation, and statements about the carcinogenic risk from coal utilization do not apply there. Although some of the same carcinogenic PNAs are involved in the health hazards from those processes, other carcinogens and also cocarcinogens will be present, and the exposed workers will not have the apparent benefits of adsorption of PNAs on soot.

Glass, N.R. Environmental Effects of Increased Coal Utilization: Ecological Effects of Gaseous Emissions from Coal Combustion, Environmental Health Perspectives (U.S.A.), 33, 1979, pp. 249-272.

Abstract: This report is limited to an evaluation of the ecological and environmental effects of gaseous emissions and aerosols of various types which result from coal combustion. It deals with NO_x , SO_x , fine particulate, photochemical oxidant, and acid precipitation, as these pollutants affect natural and managed resources and ecosystems. Also, synergistic effects involving two or more pollutants are evaluated as well as ecosystem level effects of gaseous pollutants. There is a brief summary of the effects on materials and atmospheric visibility of increased coal combustion. The economic implications of ecological effects are identified to the extent that they can be determined within acceptable limits. Aquatic and terrestrial effects are distinguished where the pollutants in question are clearly problems in both media. At present, acid precipitation is most abundant in the north central and northeastern states of the USA. Total SO_x and NO_x emissions are projected to remain high in these regions while increasing relatively more in the western than in the eastern regions of the country. A variety of ecological processes are affected and altered by air pollution. Such processes include community succession and retrogression, nutrient biogeochemical cycling, photosynthetic activity, primary and secondary productivity, species diversity, and community stability. Estimates of the non-health-related cost of air pollutants range from several hundred million dollars to 1.7 billion dollars per year. In general, these

Glass, N.R. (Continued)

estimates include only those relatively easily measured considerations such as the known losses to cultivated crops from acute air pollution episodes or the cost of frequent repainting required as a result of air pollution. No substantial nationwide estimates of losses to forest productivity or natural ecosystem productivity, which is tapped by domestic grazing animals and wildlife, or of other significant dollar losses are available.

Goldstein, B.D. Health Effects of the Gas-Aerosol Complex. Report to Special Committee on Health and Ecological Effects of Increased Coal Utilization, Environmental Health Perspectives (U.S.A.), 33, 1979, pp. 191-202.

Abstract: Combustion products derived from the burning of coal are definitely capable of producing adverse human health effects. No single component of the combustion product mixture is solely responsible. Rather, effects are due to a group of compounds, both gases and aerosols, in the effluents of stationary source combustion processes. Although incompletely defined, the individual components of gas-aerosol complex appear to be capable of interacting both in terms of atmospheric chemistry and health effects. The three primary air quality standards pertinent to regulating coal combustion all represent to some extent indirect, although reasonable, measures of this gas-aerosol complex. As a group, these standards appear to be adequate to protect human health. Conventional toxicological considerations suggest that the adverse health effects of any necessary increase in coal combustion effluents would be greatest per unit of coal in those areas that are most heavily populated and have the highest preexisting levels of the gas-aerosol complex. In order to decrease the degree of uncertainty for future decisions of this type, it is important that prospective epidemiological and air monitoring studies be initiated in conjunction with any large-scale introduction of coal use.

Hall, R.E.; DeAngelis, D.G. EPA's Research Program for Controlling Residential Wood Combustion Emissions, Journal of the Air Pollution Control Association (U.S.A.), 30 (8), 1980, pp. 862-867.

Abstract: A recently completed study shows that emissions of particulate, carbon monoxide, and organics (including polycyclic organic matter) are relatively high from residential woodburning stoves and fireplaces when compared to emissions from residential gas- and oil-fired furnaces. Since these emissions include a number of potentially hazardous compounds, the trend toward greater residential wood usage can have a negative impact on local ambient air quality. EPA is currently studying ways to operate existing stoves and design new stoves to minimize air pollutant emissions.

Herlan, A.; Mayer, J. Polycyclic Aromatics, Benzole, and Other
Detrimental Materials in Coal Stove Flues, Engler-Bunte-Institute,
University of Karlsruhe, West Germany, 1980.

Abstract: Not available.

Holvoe, P.; Ostberg, H. An Illness Directly Related to Woodchip Heating, LAKARTIDNINGEN (SWEDEN), 77 (13), 1980, pp. 1220-1221.

Abstract: An illness, which in terms of pathogenesis and clinical symptoms closely resembles the so-called trimming disease, has been diagnosed in recent years in individuals who used wood chips for house heating. Two such cases are reported in this article. Both the interval between exposure and onset of illness and the clinical course seem characteristic. Furthermore, the one case presents serology indicative of sensitization to several species of mold. Under these circumstances, the public should be warned of the danger of conversion to woodchip heating before safer handling techniques can be prescribed.

Howard, P.H.; Santodonato, J.; Basu, D.; Bruce, R. Multimedia Human Exposure to Polycyclic Aromatic Hydrocarbons and Their Association with Cancer Risk, Syracuse Research Corporation, Merrill Lane, Syracuse, NY, as presented at the 1981 International Conference of Residential Solid Fuel, Portland, Oregon, June, 1981.

Abstract: Polycyclic aromatic hydrocarbons (PAH) are one of the more important chemical classes of pollutants emitted to the atmosphere during residential wood combustion because they are well-recognized environmental carcinogens. However, humans are exposed to PAH not only from the air they breathe, but also from drinking water, food, and tobacco smoking. Thus, the total PAH human exposure must be considered in order to place in perspective the health effects of residential wood burning. The quantitative aspects of exposure to PAH from these other sources are examined and need to be compared to exposure that can be attributed to residential wood burning. In addition, extrapolation of the data on the carcinogenic effects of PAH in experimental mammals is presented to define levels of carcinogenic risk in humans.

Imhoff, R.E.; Manning, J.A.; Cooke, W.M.; Hayes, T.L. Final Report on a Study of the Ambient Impact of Residential Wood Combustion in Petersville, Alabama, Tennessee Valley Authority, as presented at the APCA Specialty Conference on Residential Wood and Coal Combustion, March, 1982, Louisville, Kentucky.

Abstract: The impact of residential wood combustion on ambient air quality was investigated in an intensive field study conducted January 28-February 13, 1981. Ambient concentrations of several pollutants and source markers were measured during nine 6- to 8-hour sampling periods in and downwind of a small residential community. Results of the measurements are reported and compared with concentrations calculated by an empirical dilution model and an area-source dispersion model.

Pollutants measured include fine particulates, coarse particulates, polynuclear aromatic hydrocarbons (PAH), NO_2 , NO_x , SO_2 , SO_4 , and volatile organics. An estimate of the fraction of fine particulates from wood combustion was made by a chemical mass balance model. Results from the model indicated that on the average about 80 percent of the fine particulates collected were emitted by residential wood combustion.

Dispersion model results compare well with ambient measurements for particulates, but for PAH, the model underpredicts by at least a factor of three. The highest concentration of benzo(a)pyrene (BaP) measured was 110 ng/m^3 . Since much of the BaP was in the gaseous phase, previous assessments of ambient BaP concentration may be low by a factor of two to three.

Jacobs, P.; Bunch, S. Health Costs of Residential Wood Combustion, Economics Department, University of South Carolina, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: The purpose of this paper is to develop an analytical form for measuring the economic impact of mortality caused by pollution from residential wood burning, and to apply the analysis to obtain preliminary estimates of these health costs. In the analytical model, relationships are posited between wood use, emissions, ambient air quality changes, mortality, and health costs. Using available data for four cities, estimates are made of the mortality impact of pollution from residential wood burning, and of the economic magnitude of this mortality in terms of added costs per pound of wood used as well as of overall economic costs. The estimates show that residential wood burning sources contribute 3/10 of one percent of all deaths; they add about five percent to the private cost of wood burning, and contribute between \$18 and \$41 million in total health costs annually.

Jouany, J.M.; Truhaut, R.; Boudene, C. Compared Toxicities of Combustion Products of Two Woods: Douglas Fir and Mahogany, Arch. Mal. Prof. Med. Trav. Secur. Soc. (France), 38 (9), 1977, pp. 751-772.

Abstract: After a preliminary discussion concerning the general methodology adopted to study the toxicity of combustion products of materials, the authors point out risks due to two kinds of wood, Douglas fir and mahogany. Any combustion of carbon-containing substances decreases the O_2 concentration in atmospheres and produces H_2O , CO_2 , and especially CO , which is considered a major toxicant responsible for toxic patterns in human fire victims. The selected fire model uses a cylindrical furnace moving for 30 minutes along a quartz tube containing wood samples (from 16.6 to 66.4 g per cubic meter of air), at 400 degrees C (smoldering conditions) and 850 degrees C (flaming conditions). The animals are intoxicated either in spontaneous ventilation (rats in restraining tubes, rabbits in "mask-cages"), or under controlled ventilation (physiogram method on curarized vigil rabbits). In controlled ventilation, pO_2 , pCO_2 , pH, CO , and $COHb$ are measured regularly in arterial blood; EEG, ECG, and arterial pressure are recorded continuously during the intoxication (30 minutes) and the immediate recovery (4 hours). The effects of toxicants on the ventilatory system are noted in the spontaneous ventilation intoxications. The evolution of the combustion is known by recording continuously O_2 , CO_2 , and CO in the atmospheres. Smoldering conditions appear to be more dangerous than flaming conditions. At equal weights, Douglas fir produces less CO_2 and CO and uses less O_2 than mahogany; therefore, it would be estimated less toxic.

Jouany, J.M. (Continued)

However, the determination of LC₅₀ shows that it is not the case. If the EEG disorders (which are normally related to CO concentration) are not as important with Douglas fir as with mahogany, the cardiovascular diseases are greater, the recoveries are worse, and the first disturbance comes much sooner. During Douglas fir intoxication, CO is more extensively fixed in the blood and COHb is made in larger amounts. The detoxification is also longer. Additionally, Douglas fir provokes more severe pulmonary damage, and acute pulmonary edema is possible. At equivalent CO concentration, the atmospheres composed of CO alone are always significantly less toxic than the ones coming from combustion and pyrolysis of mahogany and especially fir, which produces other irritant toxicants such as aldehydes.

Khesina A. Ya.; Gaevaya T. Ya.; Linnik A.B. Polycyclic Aromatic Hydrocarbon Content and the Carcinogenic Activity of Soot Extracts from Heating Systems, Institute of Experimental Clinical Oncology, Academy of Medical Science, Moscow, USSR, 1977.

Abstract: The presence of some polycyclic aromatic hydrocarbons (PAH) may increase or decrease the carcinogenic activity of other substances of the same class. A study was made of the content of a series of PAH and carcinogenic activity of soot extracts from a woodworking factory and homes with individual heating by lignite briquets. Oil solutions of ash extracts were administered subcutaneously to albino mice, separately and together with benzo(a)pyrene. Administration of soot extracts containing carcinogenic PAH and other compounds inhibited the carcinogenic process in comparison to the action of benzo(a)pyrene alone. This may be due to stimulation of metabolic degradation of carcinogenic PAH or a retardation of carcinogenesis by some substance present in soot.

Larsen, D.J. Polycyclic Aromatic Hydrocarbon Analysis by HPLC of Ambient Air Particles in a Wood-Burning Community, Dartmouth College, Hanover, New Hampshire, June, 1981.

Abstract: Not Available.

Lawther, P.J.; Waller, R.E. Coal Fires, Industrial Emissions, and Motor Vehicles as Sources of Environmental Carcinogens, IARC Science Publication, 1976, (13) pp. 27-40.

Abstract: One of the most widely studied carcinogenic agents in the environment is the polycyclic hydrocarbon, benzo(a)pyrene. As a component of soot from the inefficient combustion of coal, its association with cancer can be traced back 200 years, but its possible relevance to lung cancer as a widely distributed air pollutant has been investigated only during the past 25 years. Domestic coal fires have been shown to be important sources, and smaller amounts come from industrial sources and from motor vehicles. There is evidence now that the concentration of benzo(a)pyrene in large towns in Britain has decreased by a factor of about ten during the last few decades, as a result of changing heating methods and smoke control. In view of the overwhelming effect of cigarette smoking, it is difficult to determine whether the benzo(a)pyrene content of the air has had any important effect on the development of lung cancer, but careful analysis of trends in mortality may now throw some light on this. Among other materials with carcinogenic properties that may be dispersed into the general air, asbestos is the one that has been investigated most thoroughly. The association between exposure to asbestos and the development of lung cancer and mesothelioma of the pleura has been clearly demonstrated among people occupationally exposed to dust, but as far as the general public is concerned, any risk may be limited to the immediate vicinity of major sources. These and other hazards demonstrated among occupational groups serve as a warning, however, to maintain careful scrutiny of urban air pollutants in relation to the etiology of cancer. (37 refs.)

Lewtas, J. Comparison of the Mutagenic and Potentially Carcinogenic Activity of Particle-Bound Organics from Wood Stoves, Residential Oil Furnaces, and Other Combustion Sources, Health Effects Research Laboratory, EPA, Research Triangle Park, NC, as presented at the 1981 International Conference on Residential Solid Fuels, June, 1981, Portland, Oregon.

Abstract: Incomplete combustion products emitted from a variety of sources have been shown chemically to contain known carcinogenic polycyclic aromatic hydrocarbons, and in several cases are recognized as human carcinogens (e.g., chimney soot). These combustion emissions upon dilution and cooling contain significant quantities of filterable particles bound with condensed organic matter. The relative mutagenic and carcinogenic activity of a series of these organics is being compared from the following emission sources: residential wood stoves, residential oil heaters, diesel and gasoline vehicles. The biological activity of these emissions is being compared to the activity of complex organics from roofing tar pots, ambient collection from coke ovens, and cigarette smoke condensate emissions for which human epidemiological data have been reported. The bioassays include in vitro microbial and mammalian cell mutagenesis assays as well as in vivo skin carcinogenesis assays in rodents. Microbial mutagenesis data for the extractable organics from wood stove particulate emissions will be compared to these other sources. Both the biological activity and organic emission rate will be considered in comparing these sources and their potential environmental impact.

Lipfert, F.W. Assessment Methodology for the Air Quality Impact of Residential Wood Burning, National Center for Analysis of Energy Systems, Upton, New York, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: Data from surveys of 1977-1979 indicate that firewood usage tends to vary inversely with population density, resulting in an implied limit to the density of usage. Tests of wood stoves indicate that emissions of particulates vary inversely with heat demand, such that nighttime emissions at low combustion rates may be worse than those during maximum heat demand conditions. Finally, atmospheric dispersion rates are coupled to the driving forces of space heating so that nighttime emissions tend to have a disproportionately large impact on ambient air quality. All of these factors must be considered jointly in order to perform a meaningful assessment of the air quality impacts of increased residential wood fuel use; the results indicate that in flat terrain, primary ambient standards are not threatened by residential wood combustion. (EPA citation 06:033445)

Lipfert, F.W. A National Assessment of the Air Quality Impacts of Residential Firewood Use, Energy & Economic Analysis Division, National Center for Analysis of Energy Systems, Brookhaven National Laboratory, Upton, New York, as presented at the Specialty Conference on Residential Wood and Coal Combustion, Louisville, Kentucky, March, 1982.

Abstract: The information in this paper is directed to those concerned with the air quality impacts of residential wood combustion in urban areas. The analysis is based on an empirical relationship between wood usage and population density, which results in an upper limit to the density of wood use (cords/sq. mile). Using emission factors from the literature, estimates are made for national total emissions burdens, and calculations are carried through for both annual and short-term air quality impacts for six Northern U.S. cities for which hour-by-hour dispersion calculations were available from a previous study. The analysis indicates that achievement and maintenance of primary air quality standards in urban areas are not likely to be threatened by residential wood combustion. However, increased monitoring appears to be warranted for ambient concentrations of wood smoke particulate species of carcinogenic importance.

Martin, Werner; Koenigshofer, Daniel. Survey and Analysis of Current European Technologies for Wood Combustion, Integrated Energy Systems, Inc., Chapel Hill, NC, January, 1982. EPA Contract #68-02-3675.

Abstract: This report presents a summary of current technologies and air pollution policies pertaining to wood combustion. Twenty different concepts for wood burning equipment are described. Also included are section diagrams, size ranges, and comments regarding efficiency and convenience. Many of the system types are not currently available on the U.S. market. A list of manufacturers and their addresses is included. The report also contains emission data for many of the systems described. Emission regulations and test procedures are presented. Finally, a brief overview of health research related to suspected carcinogenic materials in wood combustion emissions is presented. This information was gathered both in the U.S. and in Europe by engineers familiar with wood combustion on both continents. The work was funded by EPA's Industrial Environmental Research Laboratory to supplement their other activities relating to air pollution from wood combustion.

Meyer, H.R. Contribution of Residential Wood Combustion to Local Airshed Pollutant Concentrations, Oak Ridge National Laboratory, TN, 1981, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: For a variety of economic, political, and supply-related reasons, a resurgence in the use of residential wood combustion (RWC) for primary and secondary heating is currently occurring in the United States. While there are a number of positive aspects to this trend, the displacement of oil, gas, and electricity as residential heat sources will result in locally increased peak and annual-average air concentrations of certain pollutants. Carbon monoxide (CO), polycyclic organic materials (POM), respirable particulates, and other hazardous materials are emitted via RWC directly into the local environment at rates greatly exceeding those associated with residential use of oil or gas. Models were developed to estimate both worst-case and seasonal-average air concentrations of key RWC emissions for representative U.S. locations. Model results are compared to available measurements of ambient and RWC-specific concentrations. Acute episodal predictions are found to exceed U.S. Environmental Protection Agency 24-hour standards for particulates, and to approach the eight-hour CO standards. By indexing to benzo(a)-pyrene, POM concentration estimates are cautiously related to potentially increased population health effects, specifically pulmonary carcinomas. The need for additional data collection and assessment work is emphasized. (EPA citation 06:027633)

Morris, Gregory. Health Effects of Residential Wood Combustion: The Implications of Environmental Stochasticity, Energy and Resources Group, University of California, Berkeley, CA, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: Rapidly rising costs for conventional energy sources have provided the impetus for a large-scale resurgence of wood as a residential fuel in the United States. Wood combustion, however, may entail significant health costs for society. Characterizing and quantifying the costs associated with wood combustion is fraught with uncertainty. One important source of uncertainty results from our tenuous understanding of the links between pollutant emissions and ambient pollutant concentrations. Pathways of dispersion and conversion of air pollutants depend on the vagaries of weather, so environmental stochasticity is an important factor in determining the ultimate impact of residential wood combustion.

This paper explores some of the implications that natural environmental stochasticity has for the health effects of residential wood combustion. A survey of the characteristics of winter climates in various regions of the U.S. leads to some preliminary generalizations about the chances for severe impacts from residential wood combustion. Since wood burning is only one of many means that home owners have for reducing their use of expensive conventional fuels, the implications that other heating technologies have for influencing the health impacts of wood combustion are also examined. Finally, possibilities are explored for controlling the effects of residential wood combustion by using regulations that are sensitive to stochastic environmental parameters.

Moschandreas, D.J.; Zabransky, J., Jr.; Rector, H.E. Effects of Wood-burning on Indoor Residential Air Quality, GEOMET Technology, Inc., Gaithersburg, MD, Environment International (England), 4 (5-6), 1981, pp. 463-468.

Abstract: Data from suburban residences in the Boston metropolitan area reveal a potential adverse impact on indoor air quality from wood-burning in woodstoves and fireplaces. Ambient pollutant concentrations at each residence were compared to corresponding pollutant levels indoors at three locations (kitchen, bedroom, and activity room). Individual gaseous pollutant samples were averaged on an hourly basis, and 24-hour integrated samples of particulate matter were obtained. Ten gaseous pollutants were sampled along with total suspended particulates (TSP). Chemical analyses further determined ten components of TSP, including trace metals, benzo(a)pyrene (BaP), respirable suspended particulate (RSP), and water-soluble sulfates and nitrates. Monitoring lasted two weeks at each residence and was conducted under occupied, real-life, conditions. Observed, elevated indoor concentrations of TSP, RSP, and BaP are attributed to woodburning. Data indicate that average indoor TSP concentrations during woodburning periods were about three times corresponding levels during nonwoodburning periods. The primary 24-hour national ambient air quality standard (NAAQS) for TSP was exceeded once indoors during fireplace use, and the secondary 24-hour TSP NAAQS was also exceeded indoors by RSP concentrations. Indoor BaP concentrations during woodstove use averaged five times more than during nonwoodburning periods. At this stage, results are only indicative, but the potential BaP from elevated indoor concentrations of TSP, RSP, and BaP, attributed to woodburning, may have long-term health implications.

Muhlbaier, J. A Characterization of Emissions from Wood-Burning Fireplaces, Environmental Science Department, General Motors Research Laboratories, Warren, Michigan, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: Wood-burning emissions were collected and characterized from a freestanding fireplace installed in the laboratory. Under the burning conditions used in this study, particulate emissions average 12 g/kg of wood burned from softwoods, 10 g/kg from hardwoods, and 19 g/kg from synthetic logs. Organic emissions increased with larger log sizes. Higher particle emissions were measured from dry wood. The particles were spheres and clusters of spheres with a mass median diameter of 0.17 micrometer. Gas emissions averaged 110 g/kg for CO, 1.5 g/kg for HC, and 0.7 g/kg for NO_x from natural woods. Particles, elemental carbon, CO₂, NO_x, and hydrocarbon emissions peaked when the temperature was the highest. Carbon monoxide emissions were more variable. Although wood burning accounts for only 3% of residential and commercial fuel usage, it is responsible for 53% of the particles and 85% of CO emissions from all residential combustion sources.

Murphy, D.J.; Buchan, R.M.; Fox, D.G. Ambient Particulate and Benzo(a)Pyrene Concentrations from Residential Wood Combustion in a Mountain Resort Community, Occupational Health and Safety Section, Colorado State University, Fort Collins, Colorado, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: Total suspended particulates and benzo(a)pyrene concentrations were highest in the center of town, averaging $61 \mu\text{g}/\text{m}^3$ and $7.4 \text{ ng}/\text{m}^3$, respectively. The mean BaP level of $7.4 \text{ ng}/\text{m}^3$ appears to be several times greater than what is expected in a major metropolitan area. Residential wood combustion is suspected as the primary source of BaP in this community.

Otis, T. (Principal Researcher) Wood Burning and Particulate Air Pollution in the Missoula Valley, as presented to the Missoula City-County Health Department, Missoula, Montana.

Abstract: The Missoula airshed during wintertime inversions is a potential hazard to the health of all residents of the valley.

Wood-burning households in the Missoula area contribute substantially to the particulate content of the ambient air. In order to determine the amount of these emissions, the Missoula City-County Health Department has conducted a wood-burning inventory. This report describes that inventory, the ensuing research, and the concluding results, projections, and comparisons to other sources.

Petty, P.; Hopp, W.; Chockie, A. Biomass Energy Utilization in the Pacific Northwest: Impacts Associated with Residential Use of Solid Fuels, Battelle Pacific Northwest Laboratories, Richland, WA, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: The Pacific Northwest Region, including Washington, Oregon, and Idaho, is the geographic area for which an impact assessment of the residential use of solid fuels has been performed. Increased use of solid fuels in the residential sector has led to a marked decline in per household use of other forms of energy. An estimate of the potential energy contained in the fuelwood burned annually and an estimate of the mean conversion efficiency of the regional capital stock of woodburning appliances lead to a reasoned assessment of the contribution of wood energy to the residential energy use in the region. The use of solid fuels has been associated with an increase in the incidence of residential fires nationally. This is also true of the Pacific Northwest Region. An estimate is made of the economic costs attributable to this source of fire incidence. An additional area of concern relates to the harvesting practices of hundreds of individuals cutting fuelwood for their own use. Statistics describing injuries and deaths per Btu in the commercial logging industry are used as a basis for an estimate of injuries and deaths resulting from the increased collection of forest residues and fuelwood by private woodcutters. This analysis indicates that the private harvest of fuelwood may be extremely costly in terms of injuries and deaths suffered by private woodcutters in the region.

(EPA citation 06:031828)

Rall, D.P.; Auerbach, S.; Friedlander, S.; et al. Report on Health and Environmental Effects of Increased Coal Utilization, Environmental Health Perspectives (U.S.A.), 36, 1980, pp. 135-153.

Abstract: The National Energy Plan announced by President Carter on April 29, 1977, proposed a significant increase in the utilization of the vast domestic deposits of coal to replace the dwindling supplies of oil and natural gas, and increasingly expensive oil from foreign sources, to meet national energy needs. At the same time, in recognition of possible adverse health and ecological consequences of increased coal production and use, the President announced that a special committee would be formed to study this aspect of the National Energy Plan. The Committee held a series of public meetings during November and December, 1977, to review a number of special papers on particular problems associated with increased coal utilization. These papers, which were prepared by scientists of the U.S. Environmental Protection Agency, the Department of Energy, the National Institute for Occupational Safety and Health, the National Institute of Environmental Health Sciences, New York University, and Vanderbilt University, provided essential background information for the deliberations of the Committee and were published in EHP, Volume 33, pp. 127-314, 1979. One paper by A.P. Altschuler, et al, is published in this volume of EHP. The Committee's basic finding was that it is safe to proceed with plans to increase the utilization of coal if the following environmental and safety policies are adhered to: compliance with Federal and State air, water, and solid waste regulations; universal adoption and successful

Rall, D.P. (Continued)

operation of best available control technology on new facilities; compliance with reclamation standards; compliance with mine health and safety standards; and judicious siting of coal-fired facilities. The Committee concluded that, even with the best mitigation policies, there will be some adverse health and environmental effects from the dramatic increase in coal use. However, these will not impact all regions and individuals uniformly. The Committee identified six major areas of uncertainty and concern requiring further investigation if the nation is to minimize undesirable consequences of increased coal utilization now and in the future. Two critical health issues of concern are air pollution health effects and coal mine worker health and safety. Two critical environmental issues are global effects of carbon dioxide in the atmosphere and acid fallout. Two additional important issues of concern are trace elements in the environment and reclamation of arid land. Finally, because of the inadequate data and methodology used in the study of these matters, the Committee strongly recommended the establishment of an improved national environmental data collection modeling and monitoring system.

Remensnyder, J.P.; von Ryll Gryska, P. Hazards of Wood-Burning
Stoves to Children (Letter), New England Journal of Medicine, 304 (15)
1981, pp. 915-916.

Abstract: Not available.

Rogers, S.E.; Savitz, D.A. Toxic Substances from Coal; Some Policy Implications for the Future, *Journal of Environmental Management*, 11 (2), 1980, pp. 165-182.

Abstract: In a technology assessment of the future use of coal in the USA, toxic substances were identified as a key issue. This study explores technical and policy implications of projected toxic chemical release. Focusing on Cd and benzo(a)pyrene (BaP) as representatives of the trace metals and complex organic compounds, respectively, 5000 km² study areas were selected in the eastern and western USA. Regional technology mixes and plant sizes were defined in accordance with a business-as-usual scenario for the years 1985, 2000, and 2030. Projected toxic effects on terrestrial and aquatic biota and humans indicate that region-wide Cd concentrations will not pose a problem, although local sites will have higher concentrations than desired. BaP, a suspected carcinogen, is primarily a product of low-temperature combustion of coal. Major sources are home coal burning and especially coal mining and processing waste pile fires. Because BaP is a compound, it can be destroyed by appropriate combustion of the coal. The emerging advanced technologies can thus significantly limit new coal-derived sources of complex organics like BaP through process control. Three primary conclusions served as the basis of policy analysis: the seemingly low toxic substances risk but high uncertainty associated with increased coal use in the future, the shortfall of knowledge with respect to the emerging advanced technologies, and the potential disparity of impact distribution from coal-use activities between specific sites and the region and

Rogers, S.E. (Continued)

nation as a whole. The dominant concern in policy regarding toxic substances in coal is the uncertainty. The scientific understanding of many facets of toxic substances is quite limited and the consequences of most policy decisions are unknown. Coal use results in the release of large numbers of toxic substances to the environment. These substances must be controlled while balancing environmental, economic, social, and human health considerations.

Romero, A.E.; Buchan, R.M.; Fox, D.G. A Study of Air Pollution from Fireplace Emissions at Vail Ski Resort, Journal of Environmental Health (U.S.A.), 41 (2), 1978, pp. 117-119.

Abstract: Not available.

Rudling, Lars; Ahling, Bengt. Chemical and Biological Characterization of Emissions from Combustion of Wood and Wood-Chips in Small Furnaces and Stoves, Swedish Water and Air Pollution Research Institute, Stockholm, Sweden, as presented at the 1981 International Conference on Residential Solid Fuels, Portland, Oregon, June, 1981.

Abstract: The emissions from the combustion of wood in a central heating furnace, wood-chips in a prechamber oven, and the combustion of wood in a modified fireplace stove and an air-tight stove have been investigated using both dried and raw fuels.

Flue gas analyses comprised aliphatic hydrocarbons, formaldehyde, acetaldehyde, simple aromatic hydrocarbons, chlorobenzenes, phenols, a range of polycyclic aromatic hydrocarbons, and mutagenicity in the Salmonella/microsome assay in addition to the conventional indices of carbon monoxide, nitrogen oxides, and particulate matter by weight.

The combustion of dried wood-chips in the furnace with a pre-chamber oven resulted in good combustion with relatively low emissions of carbon monoxide and organic compounds.

All other cases, raw wood-chips in the prechamber oven, and dried and raw wood in the furnace and the stoves, gave emissions of organic compounds in the range 10-1000 times higher than the combustion of dried woodchips. The use of raw wood or the combustion of dried wood at a starved condition in an air-tight stove may give rise to extremely high emissions of organic pollutants.

Although the health implications of wood combustion pollutants cannot be quantified, it can be calculated that it is necessary to dilute the

Rudling, Lars (Continued)

flue gases 50-50000 times in order not to exceed ambient concentrations typical of motorized urban areas (carbon monoxide, formaldehyde, ethene, benzene, benzo(a)pyrene, mutagenicity).

Shy, C.M. Toxic Substances from Coal Energy: An Overview,
Environmental Health Perspectives, (U.S.A.), 32, 1979, pp. 291-295.

Abstract: Environmental concerns over increased coal consumption are fully justified by the past history of coal use. Although improved technology has provided some safeguards, increased utilization will require mining practices, emission control technologies, and waste disposal procedures that are not yet fully integrated into the routine use of the coal energy system. The Committee on Health and Environmental Effects of Increased Coal Utilization identified six critical environmental issues that are of concern: coal mine worker health and safety, reclamation of arid lands from surface mining, the health effects of coal combustion products, toxic trace elements in coal combustion wastes, acid fallout, and global effects of carbon dioxide in the atmosphere. This presentation addresses the first four of these issues.

Steffel, R.G. An Assessment of the Need for Low Emission Performance Standards for Residential Wood-Burning Devices in the Airshed of Missoula, Montana, presented in partial fulfillment of requirements for a degree at the University of Montana, 1981.

Abstract: Not available.

Sterling, T.D.; Kobayashi, D.M. Exposure to Pollutants in Enclosed "Living Spaces", Environmental Research, 13 (1), 1977, pp. 1-35.

Abstract: The enrichment of particles such as soot and fibers in houses offers surfaces to which any number of chemicals may adhere. Many of these chemicals may be toxic. One frequent source of such toxic materials is the industrially employed adult who may carry home dusts containing harmful substances such as beryllium and asbestos on their clothing, hair, or skin. There are many other sources, generated both within and without a building. Many of the pollutants result from the combustion of coal and petroleum. Much of this benzene-soluble organic matter that adheres to and is found in heightened concentrations on particles breathed in the home is basically carcinogenic. The longer the particles remain in a home, the more they may become concentrators of toxic matter. When such particles become lodged in the lungs, they may be much more harmful than particles found in the outside air. In fact, the incidence of so-called familial occupational disease may be related to this process of particle enrichment. High levels of CO resulting from cooking should be of considerable concern. Apparently, CO levels of 200 to 300 ppm are not unlikely to occur in poorly ventilated homes, and these extremely high levels of CO (as found in Nigerian and New Guinea homes) may very likely occur also in homes in North America. This is especially so in the homes of the poor, where good ventilation is not likely to be found. Great concern has been expressed recently that tobacco smoke is a major source of pollution in the home and in public buildings.

Sterling, T.D. (Continued)

This review of data therefore takes special notice of studies that have measured levels of tobacco-related pollutants. Unfortunately, many of the studies measuring dust or CO in the smoker's environment innocently assume zero level of these contaminants in the absence of smoke so that the addition of smoking to the overall pollution can be assessed only approximately. Fortunately, it has now been shown that CO values in buildings and associated COHb levels and the contributions of smoking to these levels can be estimated with great accuracy. Where conditions of ventilation and other parameters are known, contributions of cigarette emissions to CO and COHb levels were predicted with good accuracy. With poor ventilation, it appears that smoking adds to the body burden, but not extensively. For instance, CO values in average-sized public rooms and under average conditions of ventilation appear to be increased by 7 to 9 ppm when smoking is permitted in them. Similarly, the amount of nicotine found in the air of public places ranges between 0.001 and 0.011 filter cigarette equivalents per hour. It is clear that while smoking adds to overall pollutant levels, it is only one other, and a relatively minor, source of pollution.

Truhaut, R.; Boudene, C.; Jouany, J.M. Nephrotoxic Reactions Provoked by Exposure to Wood Combustion Products. Effect of Cytochrome P450, Collect. Med. Leg. Toxicol. Med. (France), 85, 1975, pp. 291-301.

Abstract: The problems posed by the toxic products of combustion of different materials should be approached by means of an initial comparison of their effects with those of their major constituent. The authors of this paper studied the effects of CO by itself in a concentration equal to the CO found in the toxic smoke emitted from burning a wood called SIPO, and compared them with those of the smoke itself, paying particular attention to the effects on renal function. They followed this by a further experiment in which the known affinity of cytochrome P450 for carbon monoxide was studied by giving the animal an initial injection of this substance and then repeating the first experiment. As expected, they found that the cytochrome P450 diminished the toxicity in both cases.